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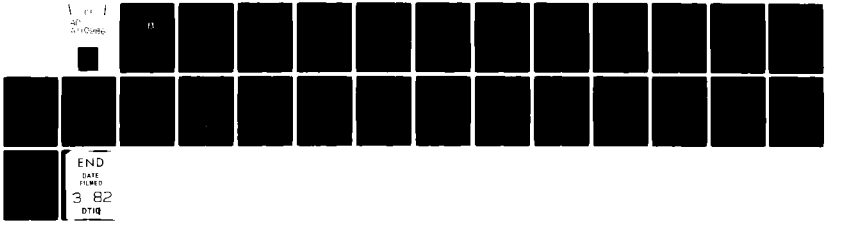

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FOREIGN TECHNOLOGY DIVISION

THE BORA PHENOMENON IN EASTERN KAZAKHSTAN

by

B.P. Alisos

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EDITED TRANSLATION

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THE BORA PHENOMENON IN EASTERN KAZAKSTAN

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Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
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З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
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К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	I, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sn	sinh^{-1}
cos	cos	ch	cosh	arc cn	cosh^{-1}
tg	tan	th	tanh	arc th	tanh^{-1}
ctg	cot	cth	coth	arc cth	coth^{-1}
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

A

The Bora Phenomenon in Eastern Kazakstan.

B. P. Alisos (Moscow)

The Chingiz Range and the entire northern and eastern parts of the Balkhash Basin are in the economy of the Kazak Autonomous Republic a region (oblast), to which at the present time special attention is being allotted in connection with the construction of the new industrial centers of Karaganda and Balkhashstroy.

Due to the vastness of its territory Kazakstan has been generally very insufficiently studied with regard to climate, and with respect to the Balkhash Region direct observations have not only been absent here until recently, but due to the topographical conditions it has not been possible to orientate onself to the Akmolinsk and the Semipalatinsk stations, which have been in operation for a long time. It has been only in the past 2-3 years that several meteorological stations have begun to operate on the shores of this lake and on the slopes of this range, but there observations are still unsystematic, and there are many gaps and considerable interruptions. Best of all in this regard is the Balkhashstroy meteorological station at Konrad; it is located 16 km to the north of Lake Balkhash on the southwestern slopes of the Chingiz Range and has been in existence for a little over two years.

With the beginning of the construction at Konrad attention has been focused on the fact, that cold, northeastern winds frequently blow

in this region in winter, and these winds are close to hurricane force; their origin has remained obscure, especially since on that side of the range (to the northeast of it), as, for example, in Semipalatinsk, there is primarily, calm weather in this season.

In August 1932, having been sent to Kazakstan to become acquainted with the climatic conditions of its little-studied regions, I had the opportunity to obtain observational materials of stations, which had only recently been opened, which could uniquely shed light on this, seemingly, local characteristic of Konrad.

It had been possible to gather more or less homogeneous and systematic material only during 1931, but this material also was incomplete for all the months; in spite of this, it was still possible to compile a systematic pattern of the phenomenon, to the extent that it was graphically expressed here.

If we examine the observations of the station at Konrad for the winter months, then it is not possible to pay attention to periods, sometimes of two-three days, and sometimes considerably longer, during which strong winds blow from the northeast quarter. It is not uncommon for the speed of these winds to exceed 20 m/s and even, apparently, more; in the majority of cases they begin suddenly, without any gradual transition, which can be traced from the adjacent times of the observations both with regard to direction, and also speed; according to the inhabitants of this area, these winds are very dry and gusty; the temperature noticeably drops every time these winds make their appearance. The boundaries of these periods are so sharp and definite, that there is no doubt, that this phenomenon is a consequence of some specific sum of conditions, more correctly, of some specific atmospheric process.

A comparison of the daily observation of the stations, indicated on map 1, for those times, when at Konrad winds are blowing from the northeast quarter with a speed greater than 10 m/s (i. e., when the phnomenon assumes a completely definite form), gives the following distribution of cases of coincidence or deviation in wind direction.

Observations during V (May), VI (June), IX Sept.), X (Oct.) and XI (Nov.) are partially absent, and were partially conducted unsystematically.

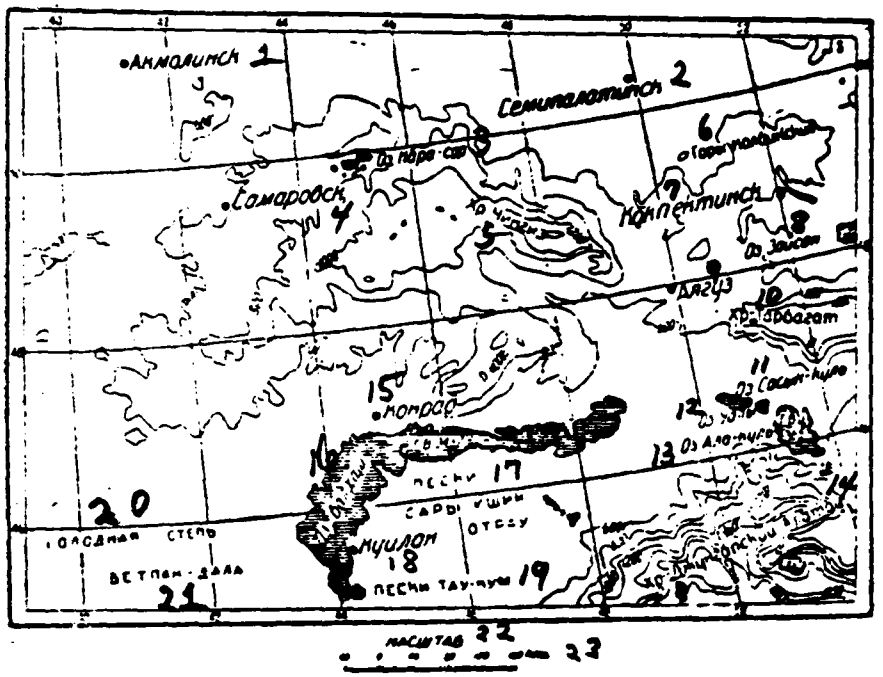

Fig. 1. Map of Eastern Kazakstan with an indication of the basic types of relief.

KEY: 1 - Akmolinsk; 2 - Semipalatinsk; 3 - Lake Mara-Sar; 4 - Samarovsk; 5 - Chingiz Range; 6 - Kolbinskiye Mountains; 7 - Kokpektinsk; 8 - Lake Zaysan; 9 - Ayaguz; 10 - Tarbagat Range; 11 - Lake Sasyk-Kil' (Lake Sasykkol'); 12 - Lake Ualy (Lake Uyaly); 13 - Lake Ala-Kul' (Lake Alakol'); 14 - Dzhungarskiy-Alatau; 15 - Konrad; 16 - Lake Balkhash; 17 - Peski Sary-Ishikotrau; 18 - Kuigan (Kuygan); 19 - Peski Tau-Kum; 20 Golodnaya Step'; 21 - Betpak-Dala; 22 - Scale; 23 - km.

Due to the deficiency of material it was not possible to carry out a complete analysis of the phenomenon with respect to all the elements and therefore we limited ourselves to a consideration of temperature and wind at the four stations, which were most interesting from our point of view: Konrad, Semipalatinsk, Kuygan and Kzyl-Orda, and also to the pilot observations at Semipalatinsk during this time.

During 1 and 2 February the temperature distribution for the stations was more or less similar, and the winds had a local character, not caused by any general process. On 3 February the pattern changes:

in Konrad a NE wind begins to blow with an average speed of 6 m and the temperature drops by 7°, at Semipalatinsk a calm ensues, and the temperature drops by 12°, at Kuygan the temperature also drops, and the wind remains the same, at Kzyl-Orda the temperature does not change, and the wind coincides with that at Konrad in force and direction.

TABLE 1.

Distribution of Wind Directions by Stations during Northeast Winds (speed higher than 10 m/s) at Konrad in 1931.

1 Станции	2 Январь		3 Февраль		4 Март		5 Апрель	
	9 Румбы и средняя скорость	10 Число случаев	9 Румбы и средняя скорость	10 Число случаев	9 Румбы и средняя скорость	10 Число случаев	9 Румбы и средняя скорость	10 Число случаев
Конрад 11	N > 10	4	N > 10	13	N > 10	2	N > 10	1
	NE > 10	9	NE > 10	18	NE > 10	5	NE > 10	14
					E > 10	1	E > 10	3
Аягуз 12	NW — 8	4	NW — 10	14	NW — 8	2	N — 10	13
	N — 8	6	N — 10	17	N — 8	5	NE — 10	6
	NE — 10	3			NE — 6	1	NW — 4	1
Семипалатинск 13	N — 2	3	N — 1	2	N — 4	1	N — 4	12
	S — 6	1	S — 3	7	S — 5	3	NW — 8	3
	14 Штиль	9	Штиль	23	NW — 6	1	Штиль	3
					Штиль	3		
Кокпекты 15	E — 1	2	E — 1	2	NW — 8	3	N — 6	6
	Штиль	11	W — 1	1	Штиль	5	W — 3	4
			SW — 2	7			NW — 4	7
			Штиль	21			Штиль	1
Акмолинск 16	NE — 4	7	NE — 7	27				
	SE — 4	3	SW — 3	4				
	SW — 2	3						
Самаровск 17	NE — 3	4	NE — 7	9				
	E — 3	9	E — 4	12				
Куйган 18	N — 1	2	NW — 1	1	NE — 7	5	NE — 6	14
	NE — 3	6	N — 3	8	E — 7	8	E — 8	1
	Штиль	3	Штиль	22			Штиль	3
Курты 19	N — 4	1	N — 4	8	N — 5	4	N — 5	13
	S — 9	2	W — 3	8	SW — 3	2	NE — 4	3
	SW — 2	4	S — 2	10	NW — 3	1	NW — 2	1
	Штиль	6	Штиль	10	Штиль	1	Штиль	1

KEY: 1 - Stations; 2 - January; 3 - February; 4 - March; 5 - April; 6 - July; 7 - August; 8 - December; 9 - Directions and average speed; 10 - Number of cases; 11 - Konrad; 12 - Ayaguz; 13 - Semipalatinsk; 14 - Calm (ash breeze); 15 - Kokpekty; 16 - Akmolinsk; 17 - Samarovsk; 18 - Kuygan; 19 - Kurty.

(See continuation of TABLE 1 on the next page.)

Table 1. (Contd.)

1 Станции	Июль		7 Август		8 Декабрь	
	9 Румбы и средняя скорость	10 Число случаев	9 Румбы и средняя скорость	10 Число случаев	9 Румбы и средняя скорость	10 Число случаев
Конрад 11	NE > 10	1	NE > 10	2	N > 10 NE > 10	1 5
Акуз 12	NE — 8	1	N — 8	2		
Семипалатинск 13	N — 6	1	N — 10	2	S — 2 Штиль	1 5
Коппехты 15						
Акмолинск 16	NE — 8	1	S — 8	2	NE — 2 E — 2	4 2
Самаровск 17	N — 1	1	SE — 8	2	NE — 7 E — 6	2 4
Кубгай 8						
Курты 19						

Weather maps for 2 and 3 February show, that by the 3rd of February an Arctic front, located on the 2nd of February to the north of Semipalatinsk, had moved to the south, and fresh Arctic air occupied the entire northern and eastern Kazakstan region. From the 3rd to the 8th of February an anticyclone distribution of winds had establised itself above eastern Kazakstan, and this distribution caused from Semipalatinsk towards the Southwest, i. e., in the direction of Konrad, a southern flow. A cloudless sky, a calm and low temperatures were observed during this time not only at Semipalatinsk, but also to a considerable extent to the north of it; fogs were noted in many places. All this indicates the presence of typical stratification of an air mass with the formation of a dense surface layer due to the cooling from the highly radiating surface; this process is not weaker in the region of Semipalatinsk, in spite of its relatively southern location. The uplands to the south and to the southwest of Semipalatinsk - the Kolbinskiy Mountains and the Chingiz Range - are the limit of the extension of this cold, dense layer.

Table 2.

The Average Daily Temperature, the Prevailing Wind and its Average Speed in February 1931.

1 Число	Конрад 2		Семипалатинск 5		Куйган 6		7 Кзыл-Орда	
	Температура в °C 3	Ветер 4	Температура в °C 3	Ветер 4	Температура в °C 3	Ветер 4	Температура в °C 3	Ветер 4
1	— 24	N — 1	— 22	SW — 4	— 25	N — 1	— 19	N — 2
2	— 25	N — 3	— 28	W — 2	— 24	N — 2	— 22	NE — 2
3	— 32	NE — 6	— 40	Тихо 8	— 32	N — 2	— 23	NE — 6
4	— 30	NE — 14	— 43	"	— 36	N — 1	— 28	NE — 10
5	— 28	NE — 14	— 42	"	— 35	NW — 2	— 26	NE — 12
6	— 29	NE — 16	— 42	"	— 36	N — 1	— 25	NE — 12
7	— 27	NE — 16	— 42	"	— 35	NW — 1	— 25	NE — 14
8	— 24	NE — 16	— 40	"	— 34	NW — 1	— 25	NE — 14
9	— 23	NE — 12	— 33	S — 3	— 30	Тихо 8	— 28	NE — 8
10	— 20	NE — 7	— 21	S — 4	— 31	"	— 23	NE — 5
11	— 19	NE — 8	— 24	Тихо 8	— 24	N — 1	— 25	S — 4
12	— 22	NE — 5	— 31	"	— 22	Тихо 8	— 22	S — 3
13	— 21	NE — 10	— 35	"	— 26	NE — 2	— 22	NE — 2
14	— 28	NE — 10	— 37	"	— 28	NW — 2	— 20	NE — 5
15	— 24	NE — 10	— 36	S — 1	— 27	NW — 3	— 19	NE — 7
16	— 19	NE — 12	— 33	Тихо 8	— 28	Тихо 8	— 20	NE — 7
17	— 21	NE — 12	— 36	"	— 28	"	— 20	NE — 7
18	— 22	NE — 12	— 25	S — 1	— 26	"	— 21	NE — 4
19	— 22	NE — 2	— 25	Тихо 8	— 27	"	— 20	NE — 6
20	— 23	W — 6	— 17	S — 10	— 26	"	— 18	NE — 4
21	— 21	NE — 4	— 18	S — 2	— 21	"	— 21	N — 1
22	— 24	NE — 16	— 28	Тихо 8	— 22	"	— 18	NE — 4
23	— 24	NE — 12	— 31	"	— 22	NE — 2	— 22	NE — 5
24	— 18	NE — 4	— 24	"	— 20	NE — 1	— 23	Перем. 9
25	— 16	NE — 4	— 24	"	— 17	NE — 1	— 19	"
26	— 17	NE — 2	— 24	"	— 15	NE — 1	— 15	N — 1
27	— 13	Перем. 9	— 15	S — 8	— 15	W — 6	— 18	NW — 2

KEY: 1 - Number; 2 - Konrad; 3 - Temperature in °C; 4 - Wind; 5 - Semipalatinsk; 6 - Kuygan; 7 - Kzyl-Orda; 8 - Calm; 9 - variable.

It is possible to consider the average height of the Chingiz Range to be about 300 m above sea level, and the height of the area, where Konrad is located, to be about 600 m above sea level, thus, the adiabatic heating in the event of the descent of an air mass should be approximately equal to 6°, whereas the Semipalatinsk-Konrad temperature differences exceed 10°, being on individual days as much as 15°. It is not possible to attribute this disparity as a whole to the condensation of vapors on the northeast slopes, since, firstly, arctic air is generally rather dry, and secondly, due to temperature inversion and during ascent it will not be cooled; thus, it is possible to assume, that, probably, the lower supercooled layer does not flow over the range in its unchanged form, but the main mass of the air flowslides over it,

enclosing it only partially in its movement. The pilot balloon observations, carried out in the second half of February at Semipalatinsk, confirrm this somehow, to the results of which we will turn below.

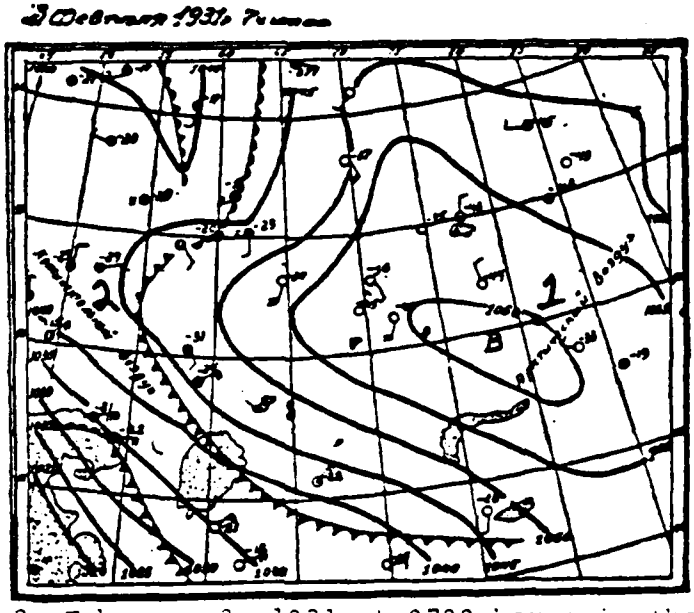

Fig. 2. February 3, 1931 at 0700 hours in the morning.
KEY: 1 - Arctic air; 2 - Continental air.

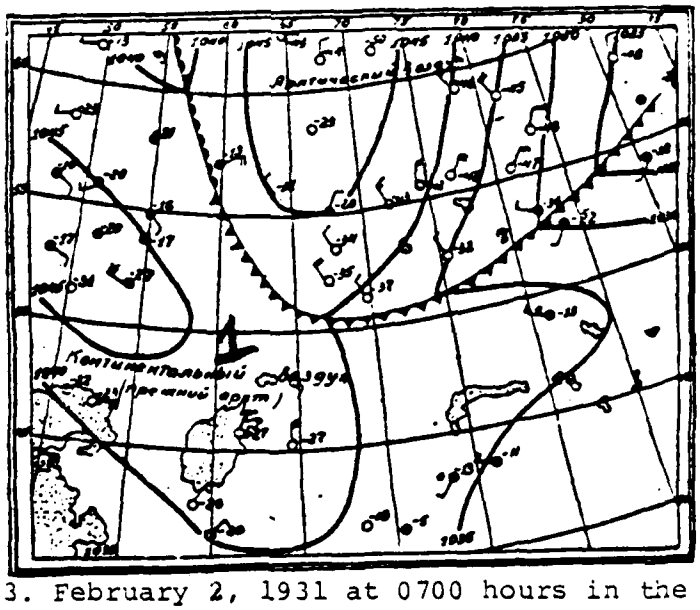

Fig. 3. February 2, 1931 at 0700 hours in the morning.
KEY: 1 - Continental air (previous Arctic air).

The air flow, passing above the range, encounters a sharp drop in

the ground surface, turns downward and obtains acceleration due to gravity. Judging from the synoptic maps, it is not possible to expect in this case an increase in the barometric gradient, to which wind speeds of up to 20 m/s would correspond, because, apparently there is none, since the phenomenon occurs in the lower air layer. This gives the basis to attribute the Konrad north-easters to winds of the gravitational type, analogous to the bora on the Dalmatian Coast of the Adriatic Sea, near Novorossiysk, or on Novaya Zemlya.

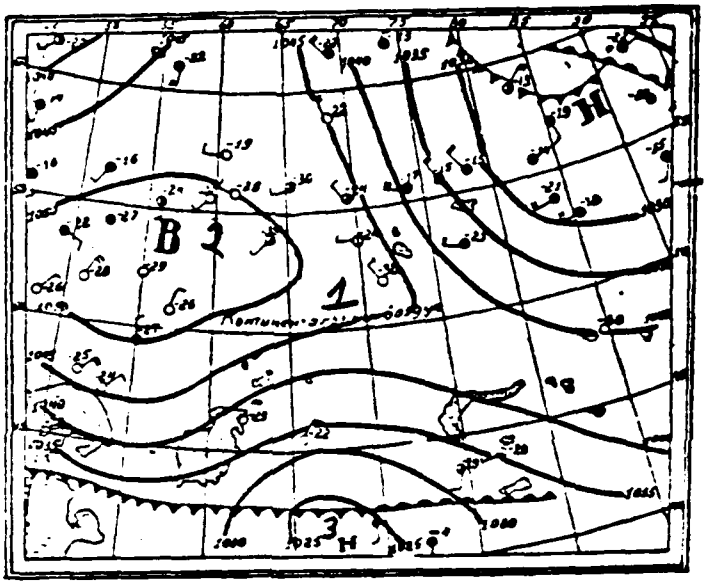

Fig. 4. February 10, 1931, at 0700 hours in the morning.
KEY: 1 - Continental air; 2 - High; 3 - Low.

On 10, 11 and 12 February the wind speed at Konrad drops below 10 m/s. On the map on the 10-th of February we see the causes of the weakening of the bora: 1) the main northeastern flow is considerably weakened due to the efflux of air to the northeast of Semipalatinsk (the wind on the 10-th of February near the surface of the Earth at Semipalatinsk is south and 2) the direction of this flow changed somewhat: it was deflected to the south, and the angle of its intersection with the range became small.

The value of the angle of intersection of the air flow with the direction of the range with a gravitational character of wind acceleration plays a large role; thus, for example, the absence of the bora

phenomenon on the southern coast of the Crimea can be explained by the fact, that the direction of the air flow is parallel to the direction of the mountain range.

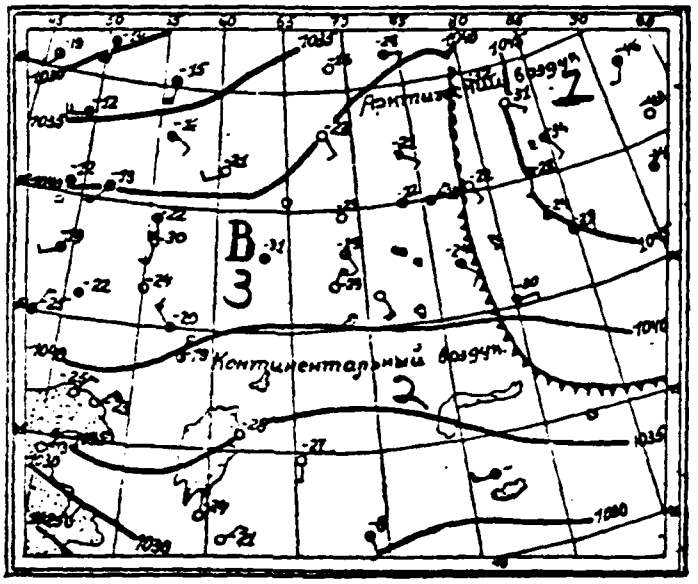

Fig. 5. February 12, 1931 at 0700 hours in the morning.

KEY: 1 - Arctic air; 2 - Continental air; 3 - High.

On February 11 at Semipalatinsk the temperature again begins to drop in connection with the arrival of a fresh portion of Arctic air.

The map for February 12 (Fig. 5) shows, that the Arctic front had just passed Semipalatinsk and was moving on to the west. At Konrad on this day the northeast wind still does not have great force, since ahead of the front, and along it, there is an efflux of air to the north, and in the region of the Chingiz Range the wind has a northeast direction, i. e., one, which coincides with the direction of the range itself. By the morning of the 13-th of February the Arctic air had moved to the west as far as the Urals, and in the rear of the front a northeastern flow had established itself, i. e., one intersecting the range at an angle, close to a right angle, as a consequence of which the wind at Konrad had intensified. This situation was maintained right up to the 18-th of February, until North-Eastern Kazakstan was

in the southern half of an anticyclone.

During the 13-th and 14-th of February there were pilot balloon observations at Semipalatinsk (Table 3), they were indicative of two relationships: 1) wind speeds at an altitude over Semipalatinsk less, than near the surface of the earth at Konrad, especially on the 13-th of February, by which is confirmed the consideration, presented above, concerning the gravitational character of the Konrad north-easters, and 2) both these pilots yiedl a sharp decrease in wind speed at an altitude of about 2.5 km with almost unchanging direction, which indicates the existence of inversion, in other words, the stratification of the air mass. On the 14-th of February the boundary of the inversion was more sharply expressed and seemingly lies somewhat higher, than on the 13-th of February, while the pressure above Semipalatinsk increases, and the temperature below attains the minimum; apparently, the cold mass thrust in with its thickest (vertical) part; however, this did not cause an increase in the force of the bora at Konrad, since the rapid effluence of air occurs primarily in the lower layer and its intensity depends little on the vertical thickness of a given mass on the whole.

On the 18-th of February the bora weakens and on the 19-th of February it ceases due to the fact, that the anticyclone moves towards the south, and Eastern Kazakstan finds itself in its northern half with southwestern winds.

On the 22-nd of February there is a new influx of Arctic air.

The pilot, released on the 22-nd of February, beginning at an altitude of 0.5 km, detects a northwestern flow, so that the necessary condition for the appearance of a bora at Konrad is seemingly absent - the presence of a general northeastern flow, - but it is necessary to note, that the launching of the pilot took place in the morning, whereas the bora appeared in the middile of the day at Konrad, when the front had managed to move away to the southwest. Moreover, on the daytime map on the same date at Semipalatinsk a sharp bending of the isobar is indicated, which is not even noticed on the morning map due, perhaps, only to the incompleteness of the material, and, finally, the

wind speeds, indicated by the pilot, are low (2-3 m), so that in general it is difficult to indicate any specific direction.

Table 3.

Pilot Balloon Observations at Semipalatinsk during a Bora at Konrad in 1931.

Число 1	Флюгер 2	Обл. 3	0.5 км	1.0 км	1,5 км	2,0 км
9.I	ESE — 3	3ACu / 1St	185/8	251/4	349/9	5/8
13.II	W — 2	2/2 FrSt	19/4	50/5	62/8	68/4
14.II	WNW — 5	0/0	352/5	24/9	81/11	95/11
18.II	Тихо	10/10	306/4			
22.II	WSW — 1	10C/St / 2St	307/5	200/3	348/8	315/2
13.III	W — 4	9/9 StCu	284/7	314/7		
9.IV	NW — 2	0/0	53/9	55/5	67/4	46/3
16.IV	N — 7	1/1 StCu	25/8	38/14	52/15	51/15
17.IV	N — 6	0/0	28/10	45/16	53/14	55/15
18.IV	NE — 7	0/0	54/11	69/8	62/12	57/14
21.IV	W — 3	4/0 Cl	32/8	30/2	54/4	110/2
31/VIII	N — 8	1/0	9/6	26/18	23/16	18/14
8/XII	E — 8	0/0	112/4	121/3	249/4	338/9

KEY: 1 - Date; 2 - Anemoscope; 3 - Clouds.

Table 3. (Contd.)

2,5 км	3,0 км	4,0 км	5,0 км	6,0 км
4/1				
64/8	37/4			
4/2	822/9	805/3		
29/3	16/3	11/6	9/10	14/11
41/10	19/14			
49/14				
118/1	121/2	245/1	285/4	30/4
850/11	2/13	845/10	858/16	825/17
840/6	838/7			

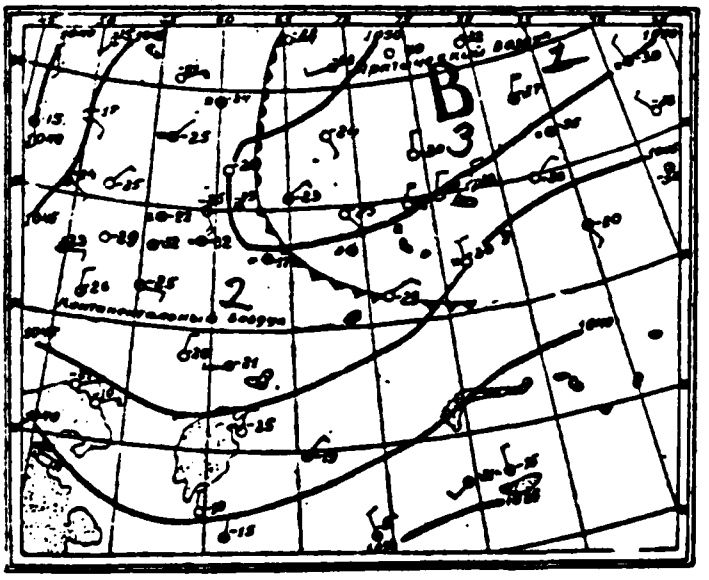

Fig. 6. February 22, 1931 at 0700 hours in the morning.

KEY: 1 - Arctic air; 2 - Continental air; 3 - High.

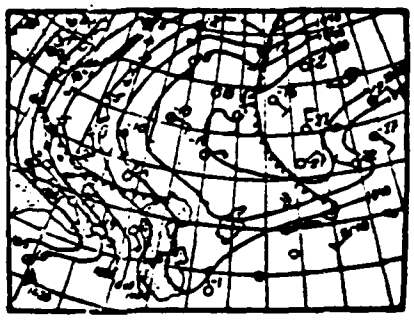

Fig. 7. February 22, 1931 at 0700 hours in the morning.

On this occasion not one anticyclonal system was created in the cold mass, but several centers were formed, due to which conditions were not present for a stable northeastern flow over Kazakstan; the bora remained at Konrad for a total of 2 days - the 22-nd and the 23-rd of February. On the third day the average wind speed fell to 4 m, in spite of the considerable difference in temperatures on one and the other side of the range (Semipalatinsk-Konrad); on the 25-th and the 26-th of February this difference was about 8°, i. e., not less, than in the preceding days, when the bora was in full development, for example on the 23rd of February.

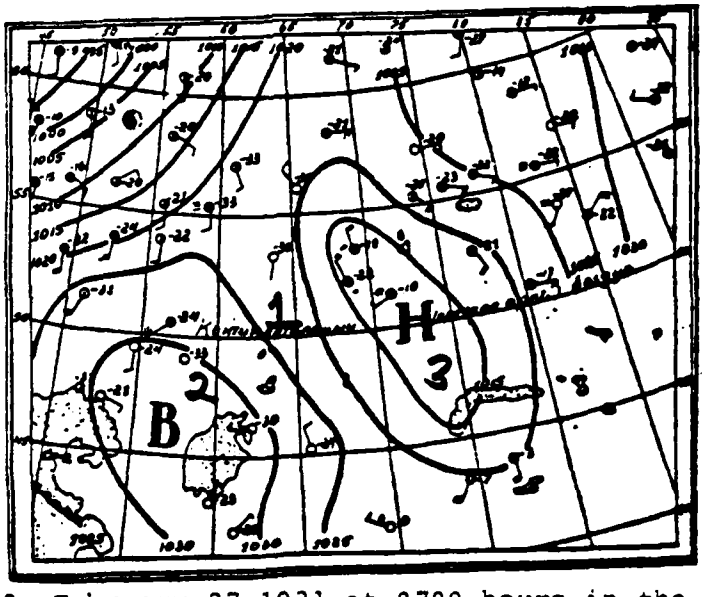

Fig. 8. February 27 1931 at 0700 hours in the morning.
KEY: 1 - Continental (former Arctic) air; 2 - High; 3 - Low.

Finally, on the 27-th of February we have such a synoptic situation, in which a bora is not possible.

What is occurring at other stations during the bora at Konrad? Table 1 shows, that (in February) the greatest frequency and intensity of northeastern winds were observed at Konrad, then - in order of decreasing degree - at Ayaguz, at Samarovsk, at Akmolinsk. If we pay attention to the relief, then this is completely understandable: the orientation of the range in regard to the direction of wind flow is most favorable opposite Konrad, and opposite Konrad the range has the greatest height, which gives the greatest value of descent during the flow of air masses.

If it is calm at the Kokpekty station, in the Kolbinskiy Mountains, and to the south of Semipalatinsk, and although there is no data for the northern part of the Zaysan Basin, but, probably, it is also calm there, since a bora is not a consequence of the fact, that cold air, accumulated behind a range, flows over it, as if over the edge of a vessel, there, where this edge is lower, regardless of dependence on direction, and this is the same for the basic air flow, obtained at a given site, due to the conditions of the relief, the acceleration due to gravity, i. e., the direction of a bora should be close to the direction of the main flow, although it can also be somewhat deflected from it depending on how a mountain slope is oriented.

At the stations beyond Lake Balkhash (Kuygan, Kurty) the bora phenomenon is reflected in the form of weak northern winds, and that is for a small number of cases, in the remainder there are observed either a calm or weak winds of diverse directions, which is, probably, the result, mainly, of the thermal effect of the lake itself, which even in cold winters does not completely freeze, thus representing a surface of about 25 degrees warmer than the air mass flowing over it during the bora. This temperature difference causes a strong ascending flow, by which is explained the horizontal speed of the flow.

The vast deserts between Balkhash and Syr-Dar'ya are not a substantial for cold wind in winter, since the snow covers are not too well heated, but nevertheless the great distance weakens the force of the

wind, and at Kzyl-Orda we have simply strong northeastern winds without any specific features of a bora; moreover, it is necessary to keep in mind, that when a northeast wind blows at Kzyl-Orda, then only in separate cases can these be the same air masses, which before this descended from the Chingiz Range and received corresponding acceleration, and thus it is not always possible to set the dependence of the wind force at Kzyl-Orda on the force of the bora at Konrad.

Let us turn to cases of bora in spring. The period of 15-21 April is most clearly expressed; let us give for it, as well as for February, a table of the daily distribution of the average diurnal temperatures and wind for the same stations.

On 16 April an Arctic front passed Konrad, which was indicated by a temperature which dropped by 11°, the wind speed increased to 18 m/s, and it is possible to consider this day as the beginning of the bora.

However, on the day before and east wind blew with an average speed of 9 m, whereas the temperature was the same as previously, and it seemed, that the front hat not yet passed; thus the wind acquires gravitational acceleration not only in the dense, "fresh" arctic mass, but also in the "old" arctic mass, which had generated in a certain manner into continental air.

The map for 16 April portrays the situation known from the February maps, the analysis of which it is not necessary to repeat. But it is necessary to pay attention to the wind distribution pattern at the stations, presented in Table 4: during the bora at Konrad winds from the southeast quarter (of average force) blew both beyond the range and on the south shore of Balkhash (in contrast to the winter months). Such a variation is explained by a change in the character of the underlying surface. In the winter months the highly radiating snow cover on the immense expanse of the northern part of Asia creates a thick lower layer, which is distinguished by great density, in which, apparently, the bora mainly arises, and thus the diverse local features so noticeably affect the degree of intensity and the propagation of this phenomenon. In spring, when the greater part of the territory is free from snow, the indicated stratification has not been carried out and the

Arctic mass has a structure, completely corresponding to an unstable state, as a "cold mass;" thus there is no lower, seemingly, independent layer, in which the phenomenon occurs independently of the entire mass. The unstable state of the "cold" Arctic mass, clearly expressed in spring (and then in summer) considerably abridges the duration of individual cases of bora and in particular, as it is possible to note, the duration of its greatest stress.

Table 4.

The Case of Spring Bora in Konrad

1 Апрель 1913 г.	Конрад 2		Семипалатинск 3		Куйган 4		Кзыл-Орда 5	
	Температура в °С 6	Ветер 7	Температура в °С 6	Ветер 7	Температура в °С 6	Ветер 7	Температура в °С 6	Ветер 7
14	10	Перем. 8	1	NW — 6	12	NE — 2	18	NE — 2
15	10	E — 9	— 2	N — 3	14	NE — 6	20	Перем. 8
16	— 1	NE — 18	— 2	N — 8	3	NE — 8	15	SW — 3
17	+ 1	NE — 18	— 1	N — 7	3	NE — 6	10	NE — 2
18	6	NE — 16	+ 2	N — 6	3	NE — 4	9	NE — 8
19	5	NE — 14	3	NW — 10	4	NE — 6	9	NE — 16
20	7	E — 10	3	Перем. 8	7	NE — 4	10	E — 6
21	10	Перем. 8	4	Штиль 9	7	Перем. 8	10	Перем. 8
22	11	SW — 5	9	Штиль 9	11	Перем. 8	11	N — 3

KEY: 1 - April 1913; 2 - Konrad; 3 - Semipalatinsk; 4 - Kuygan; 5 - Kzyl-Orda; 6 - Temperature in °C; 7 - Wind; 8 - Variable (shifting); 9 - Calm (ash breeze).

The pilot balloon for 16 April (Table 4) shows, that in the air mass, actually, there is not stratification, since the wind speed continuously increases with altitude. On the 18-th of February there was a certain weakening of the wind force at an altitude of 1 km, which was noticeable but it was insignificant.

On the morning of April 21 a northeast wind was still blowing at Konrad, but then it was replaced by a northwest wind. The synoptic map for the 21-st of April does not sufficiently depict the variation in the situation, and only on the following day does the situation become clear: the baric relief becomes complex due to the replacing of the air

masses and over the Chingiz Range there are no longer conditions for a northeast flow.

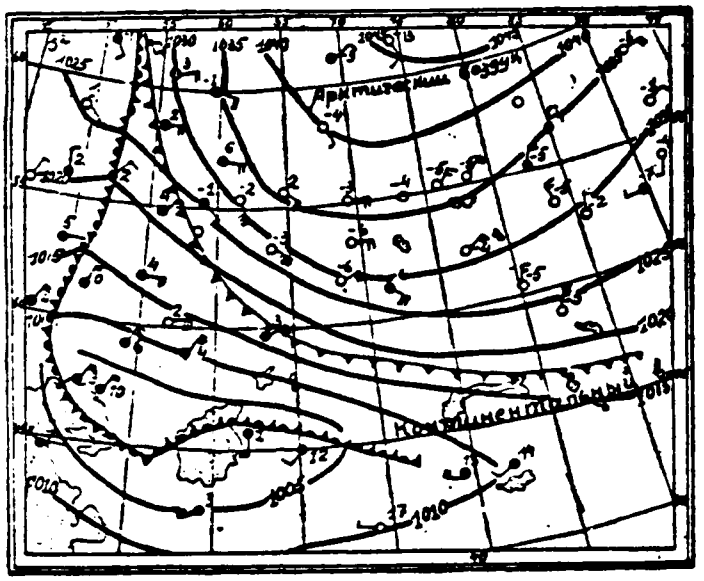

Fig. 9. April 16, 1931 at 0700 hours in the morning
KEY: 1 - Arctic air; 2 - Continental air.

The pilot for 21 April is interesting, which at an altitude between 1.5 and 2 km passed through the interface of two air masses.

In the winter months the number of days with bora ia very small, since the conditions for the appearance of an anticyclone are very rarely realized over Eastern Kazakstan. In 1932 it is possible to indicate one case in July and one in August (materials are absent for May and June). The synoptic conditions of these cases differ very little from those just examined. The phenomenon also occurs in a cold mass, but with lesser intensity as a consequence of the vertical instability of the mass indicated above and generally due to the lesser density of the air, especially in the lower layer, in comparison with the winter months.

The coming in of the cold air in the July case, apparently, is necessary to attribute to the evening of the 20-th of April, since the temperature dropped considerably and a squall with precipation passed. It is possible to consider the days of 21 and 22 July as days with bora,

but its force was sufficiently great only in the beginning, i. e., on the morning of the 21-st, until the air had time to be heated and had lost the necessary density. We also see the same thing in August; apparently, this peculiarity is characteristic for summer cases of bora. The little expressed diurnal variation in temperature and humidity draws attention to itself, especially from noon to evening, which is explained, on the one hand, by the fact, that the underlying surface cannot have a great effect on a fast-moving air mass in a thermal regard, and on the other - by the dynamic heating of the mass itself during the descending motion. The absence of cloudiness and the general dryness of the air are also a result of the descending motion.

Table 5.

Cases of Summer Bora at Konrad in the year 1931.

Месяц и число 1	Ветер в м/сек 2	Температура в °C 3	Относительная влажность 4	Облачность 5 общ. 6	Облачность 5 ниж. 7	Примечание 8
VII; 20; 7 ч. у. 10	Тихо 12	28,4	69	10	5	Дождь (11 мм) с сильным ветром перед вечером 9
13 ч. 11	Тихо 12	32,6	14	10	0	
21 ч. 11	N — 3	19,6	100	8	8	
21; 7 ч. у. 10	NE — 16	18,6	71	10	3	
13 ч. 11	NE — 7	27,0	21	0	0	
21 ч. 11	NE — 5	23,1	29	0	0	
22; 7 ч. у. 10	ENE — 7	17,8	84	0	0	
13 ч. 11	ENE — 5	25,6	17	0	0	
21 ч. 11	NE — 3	22,6	29	0	0	
VIII; 30; 7 ч. у. 10	SW — 5	17,8	61	0	0	
13 ч. 11	S — 12	29,4	24	3	3	
21 ч. 11	Тихо 12	26,2	39	0	0	
31; 7 ч. у. 10	NE — 16	15,4	73	0	0	
13 ч. 11	NE — 7	25,8	25	0	0	
21 ч. 11	NE — 1	22,2	76	0	0	

KEY: 1 - Month and date; 2 - Wind in m/s; 3 - Temperature in ^{o}C; 4 - Relative humidity; 5 - Cloudiness; 6 - general; 7 - low; 8 - Note; 9 - Rain (11 mm) with strong wind before evening); 10 - hours in the morning; 11 - hours; 12 - Calm.

The examined winter, spring and summer cases of bora make it possible to detect to a known degree the basic features of the annual variation in the phenomenon even from the small amount of material, which is in the observations. It is possible to assume, that the bora on the western slopes of the Chingiz Range is most developed in January and

February, since at this time the Arctic air most frequently and most deeply penetrates into the depth of the Asian continent and with a general anticyclone distribution of the winds creates over Kazalstan a stable northeast flow.

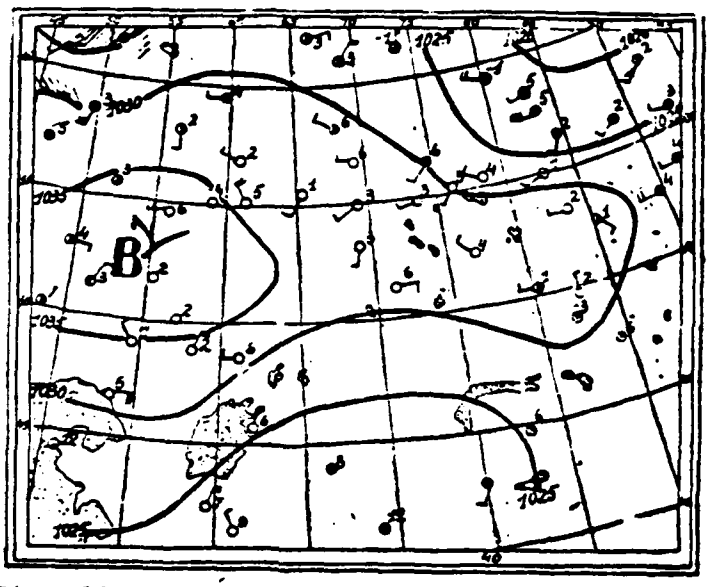

Fig. 10. April 21, 1931.
KEY: 1 - High.

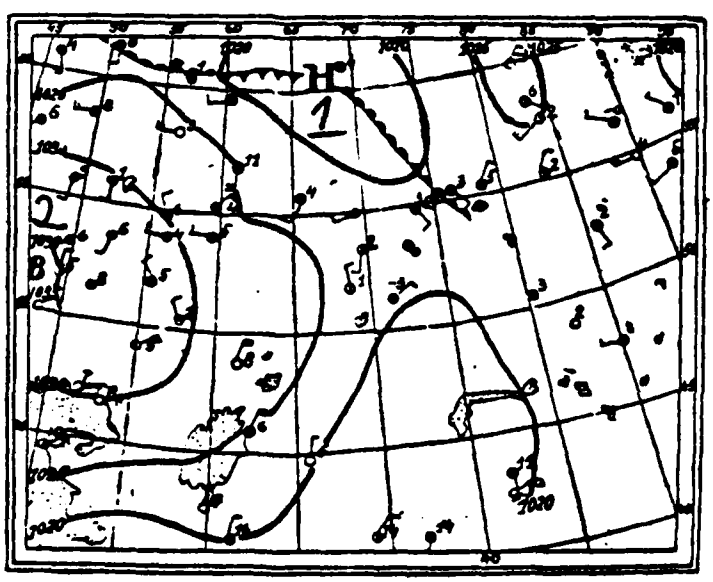

Fig. 11. April 22, 1931 at 0700 hours in the morning.
KEY: 1 - Low; 2 - High.

The general speed of this flow is low and only because in the winter months the gravitational wind phenomena occur primarily in the lower, most cooled and densest layer and is distinguished by great force. Thus, with that density of the lower layer in the Arctic air, which we have in the winter months, a comparatively weak general flow is sufficient, in order to obtain in the descent from the range speeds of up to 20 and more meters per second. What is the role of the gradient of general atmospheric pressure, measured near the surface of the Earth? Apparently, it is small, and if we seek the dependence between the speed of the bora and the pressure gradient, then it is necessary to measure the partial gradients for the different air layers. As an illustration of this can serve the synoptic situation on 9 and 10 February 1931, when the barometric gradient increased due to the the low-pressure region, which approached from the southwest, however, the wind speed at Konrad on these days ont only did not increase, but considerably decreased (Table 2). And this is completely natural: if the warm air, with which the low-pressure region is connected, had the possibility to move to the southeast, this means, the the cold air retreated, i. e., the speed of the main northeast flow decreased, and together with it the force of the bora. Moreover, it is necessary to keep in mind, that the latter is a phenomenon of the lower layer of the atmosphere, and those pressure changes, which are caused by the redistribution of the masses in the higher layers, cannot have a great effect on it.

In spring the conditions are absent for the formation of a lower dense layer in the cold mass; on the other hand, the heating of the soil by the sun causes the the regeneration of Arctic air, decreasing its density and increasing the vertical thickness. This, first of all, affected the fact, that for obtaining speeds higher than 10 m/s by the air sliding down from the range a considerably greater initial speed (the speed of the main flow) is necessary, than in winter. The pilot observations for the 16-th, 17-th and 18-th of April (Table 2) indicate a changed situation; first, the wind speeds at high elevation are considerably greater, than in January, February and December, and, secondly, there is none of the above-mentioned stratification, which so characteristically appears on February 13 at an altitude of of 2 km, on February 14 at an altitude of 2.5 km and on February 22 at an altitude of

1 km; on April 16, 17, and 18 we have an increasing wind speed without any interruption. Then in connection with the absence of a lower dense layer the northeast direction of the wind spreads over a considerably larger territory: 16 indications at Kurty and Kuygan, 15 indications at Semipalatinsk and 13 indications at Kokpekty of winds with a northern component, although less in their speed than 10 m/s correspond to 18 diurnal observations of bora in April at Konrad. The number of cases of bora in April is less, than in February, but is still significant.

In summer (July, August) we have only three indications of bora, and many details, which distinguish summer cases, thus, while they are sliding away, but apparently, everything, that has indicated the peculiarities of spring cases, occurs here, only it should be expressed to a greater degree, since the heating of the underlying surface in summer by the sun, certainly, is more pronounced. If we judge from single cases, then it is possible to note one more important fact, which distinguishes the mechanism of the appearance of bora in summer: due to the great heating of the soil, especially on the slopes of the range turned towards the south, similar conditions for the rapid sliding of the air downward exist only at first after the entrance of the cold air; a bora is thus connected with the time of the passage of a cold front and rapidly comes to an end.

The frequency of bora in summer, as we see, is considerably less, than in winter and in the transitional seasons.

Fall, unfortunately, is completely omitted in the observations of 1931 and it is not possible to indicate anything about it.

The great number of cases in December depicts a situation analogous to the situation in January and February.

Having examined the conditions of the appearance of bora and the properties, which distinguish it in the various seasons, it is necessary to dwell on the climatological side of the question: wasn't 1931 an exception and how much is the bora phenomenon generally characteristic for the climatology of this region?

Having established the dependence of the bora phenomenon on specific dynamic processes in the atmosphere, the frequency of which from year to year by seasons has been more or less explained, it is possible to make a judgement about the degree of probability of the phenomenon itself. In winter (January and February) Northeastern Kazakstan is usually included in the southern half of the anticyclone system, caused by the entrance of Arctic air; a stable northeastern flow, which, as was examined above, is also a condition of the appearance of the bora on its southwestern slopes, was accomplished by this over the Chingiz Range.

In spring and subsequently towards summer a stationary anticyclone is formed more rarely, yielding either to regions of variable (shifting) winds or, on the other hand, to a cyclonic distribution; as a result of this the bora in summer is rare and is brief. In December stationary anticyclones again seemingly begin to appear in Eastern and Western Siberia, but they are not so long or so intensive, as in January and February, when the supplies of Arctic air are the greatest.

Thus, the variation in the bora by months in 1931 is exceptional and agrees with the annual distribution of dynamic processes, known to us.

The absence up to the present time of information about the phenomenon being described leads now in questions of economic planning and construction in Kazakstan to difficulties, and sometimes directly to incorrect decisions. Thus, for example, the planning of civil aviation lines does not take completely into account the impossibility of flights in the wintertime along the southwestern slopes of the Chingiz Range from Ayaguz to Karaganda, whereas flights, carried out over the other side of the range, would be under especially favorable conditions, due to the calm air. Because of the bora all test flights along the Taldy-Kurgan-Konrad line over Balkhash were unsuccessful, while it would be necessary to fly, skirting Balkhash from the west and have, thus, the wind from the front, and not from the side. Most difficult is a flight from Ayaguz to Semipalatinsk over the range, when for whole weeks at a time due to the bora aircraft cannot fly out of Ayaguz; how

in this case does one get out of the difficulty, without special anemometric investigation, is difficult to say, but one thing is clear, that it is not possible in Ayaguz under a very, so to say, airfall to plan a junction airfield. In the construction of Balkhashstroy only now have they come to agreement with the bora in practice, and in connection with this there arises the question concerning the partial replanning of the city. The climatology of the Kazakstan bora plays an important role also in the cattle breeding industry. From the point of view of power engineering resources of Kazakstan the bora of the western slopes of the Chingiz Range is of extreme interest not only due to its considerable force and duration, but also because it has its primary propagation in winter, when at the majority of other points of Eastern Kazakstan the wind is either absent or its speeds do not exceed 5 m.

In view of the fact, that the tempo of development of our country urgently requires the fastest climatological illumination (elucidation), it seemed expedient to us to give a description and a possible analysis of the bora phenomenon, although from very limited materials.

The Central Institute of Experimental Meteorology and Hydrology.

ABSTRACT

The Bora Phenomeon in Eastern Kazakstan

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In the summer of 1931 the author was sent by the Institute of Geophysics of the USSR to study the climate of the little known regions of Kazakstan.

During this trip he was interested in the phenomenon of NE winds of hurricane force on the north shore of Lake Balkhash.

These winds, being local in character and coming most frequently in the winter months, interest had arisen in them only during the past few years due to the development of industrial construction in Kazakstan.

The regional cause of this phenomenon was not the only bright spot, because the neighboring meteorological stations did not know it.

The materials, received by a station recently founded in this locality, had obtained the possibility to find out the fact, as to which place had groups of days preferably in winter, with NE winds of 15, 20 and more m/s; the air temperature falls, in this case, lower than -20°.

In comparing the results of the observations of the network of stations of North Kazakstan and according to the analysis of the sinoptic charts it is clear, that we have here the process of the flowing (the fall) of cold masses of Arctic air on the SW side of the Chingiz Range (between Semipalatinsk and Lake Balkhash).

The same dynamic situation of "bora" (northern storms) is observed on the Adriatic coast of Dalmatia, on the Caucasus coast of the Black Sea and on Novaya Zemlya. Consequently the phenomenon of NE storms on Balkhash should be considered "bora."

The fact, that the "bora", as is well known, is the process of the flowing of cold air on the slopes of relief, permits us to predict the the lie of the "bora", on the basis of the relief and the dynamic situation.